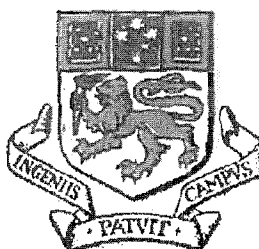

GEOLOGY AND GEOCHEMISTRY OF THE WARRABARTY CARBONATE-HOSTED Zn-Pb PROSPECT, PATERSON OROGEN, WESTERN AUSTRALIA

by

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For Jac and Sam

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ABSTRACT

Warrabarty is a sub-economic, carbonate-hosted Zn-Pb prospect in the Great Sandy Desert of Western Australia. The prospect occurs beneath 80 to 150 m of younger cover rocks and is known only from drilling. Mineralisation has been intersected over a strike length of approximately 2.5 km and has been tested by approximately 6 km of diamond drill core from 29 drill holes.

The prospect occurs within ?Meso- to Neoproterozoic, sub- to midgreenschist facies metasediments of the Throssell Group of the Paterson Orogen. In addition to Warrabarty, the Throssell Group hosts mineralisation at the Nifty copper deposit and the Maroochydore and Rainbow copper prospects. The Warrabarty prospect is hosted by the upper Broadhurst Formation of the Throssell Group, which has been affected by four deformations. Of these, D₂ is the most significant, producing northwest trending, gently plunging open to tight folds and a variably developed northeast dipping cleavage. In the vicinity of the prospect the Broadhurst Formation consists of a thick (> 400 m) sequence of carbonaceous dolostones (termed dark dolostone) with lesser conformable, organic poor dolostones (termed dolostone A) and minor fine grained limestones. Dolomitisation is interpreted to have occurred during late diagenesis in the burial diagenetic regime.

A later generation of medium to coarse grained, light grey, unimodal, nonplanar dolostone, termed dolostone B also occurs. Dolostone B forms interbeds, crosscutting zones and a >400 m thick, partially crosscutting, massive unit in the southern part of the prospect area. Abundant examples of dolostone B crosscutting bedding and pressure solution in earlier dolostones indicate a later timing for dolostone B, and show that it formed by replacement of dark dolostone and dolostone A. Dolostone B is spatially associated with mineralisation and is interpreted to have formed as an alteration feature immediately prior to and synchronous with mineralisation.

Warrabarty mineralisation occurs as breccias, veins and zones of disseminated to massive sulphide. Typical mineralisation is Zn-rich and low grade (typically 3-6 wt % Zn + Pb), with minor zones up to 40 wt % Zn + Pb; Cu, Ag and As values are low. Sulphide mineralogy is simple consisting of low Fe sphalerite, pyrite and galena with minor chalcopyrite and extremely rare arsenopyrite, bornite and chalcocite. Gangue mineralogy consists of four stages of dolomite, minor quartz, pyrobitumen and phlogopite. The mineralisation has been subdivided into two major paragenetic stages: grey stage and white stage. The grey stage predates the white stage and was responsible for introduction of almost all Zn and Pb into the prospect. White stage mineralisation remobilised Zn and Pb and introduced very minor Cu.

The most widespread mineralised breccia type at Warrabarty is typically clast supported and consists of angular to rounded dolostone B clasts in a cement of sphalerite and dolomite, with

minor pyrite \pm galena. Brecciation and porosity creation was caused by a combination of fracturing and carbonate dissolution, prior to mineralisation and dolostone B alteration. In these breccias and most veins, sphalerite (\pm pyrite) was the earliest mineral deposited, forming rims on breccia clasts and selvages to veins; galena occurs consistently later in the paragenesis than sphalerite. In some breccias and veins, sphalerite has replaced clasts and wall rock, resulting in higher Zn grades. Sphalerite is well zoned, has abundant solid pyrobitumen and carbonate inclusions and contains dissolution surfaces which cannot be correlated between samples. The minor Cu introduction that occurred during the white stage forms chalcopyrite disease of sphalerite.

Grey stage mineralisation occurred after late diagenetic dolomitisation and bedding parallel pressure solution, but is overprinted by S_2 fabrics. Many white stage veins have fibrous crystal morphology and branching, tapered, sigmoidal shapes typical of syntectonic veins and are interpreted to have formed during D_2 .

Primary fluid inclusions from grey stage sphalerite show a bimodal distribution of trapping temperatures; with an early low temperature population (165°C - 205°C) and a paragenetically later higher temperature population (215°C - 245°C). These fluid inclusions have low first melting temperatures indicative of complex CaCl_2 (\pm Mg, Fe, K) bearing brines and salinity estimates from final ice melting temperatures range from 22 - 25.5 wt % total salts. Grey stage dolomite trapping temperatures (227°C - 276.5°C) are higher than sphalerite temperatures, although first melting temperatures are similar and salinity estimates (14.5 - 26 wt % total salts) are also comparable with sphalerite. White stage fluid inclusions associated with chalcopyrite disease have trapping temperatures ranging from 300°C to 400°C . First melting temperatures for these fluid inclusions indicate CaCl_2 bearing brines and salinities have been estimated at 15 to 22 wt NaCl and 2.5 to 5.5 wt % CaCl_2 .

Carbon and oxygen isotope data from least altered Throssell Group carbonates range from: $\delta^{13}\text{C}$ + 2.7 to + 6.1 ‰ and $\delta^{18}\text{O}$ 21.7 to 27.1 ‰. Dolostone B alteration and grey stage cements range from: $\delta^{13}\text{C}$ + 0.4 to + 6.8 ‰ and $\delta^{18}\text{O}$ from 21.7 to 28.4 ‰ and show almost complete overlap with the least altered host rock field. White stage dolomite carbon and oxygen isotope compositions range from $\delta^{13}\text{C}$ + 0.9 to + 4.5 ‰ and $\delta^{18}\text{O}$ 16.7 to 27.5 ‰ and define a relatively steep trend on $\delta^{18}\text{O}$ - $\delta^{13}\text{C}$ plots which is most consistent with water-rock interaction.

Grey stage sulphide $\delta^{34}\text{S}$ compositions range from + 1.5 ‰ to + 20.4 ‰ with a distinct mode at 11 to 14 ‰ and a sharp cut-off at approximately 14 ‰. The data are interpreted to reflect mixing between an isotopically light host rock sulphur source and an introduced, reduced sulphur source of approximately +14 ‰. The heavy, introduced sulphur was derived from Proterozoic seawater (as connate brines or by dissolution of evaporites) shifted to lighter values by thermochemical

sulphate reduction and mixing with biogenically reduced sulphur, far removed from the site of mineralisation. White stage sulphide $\delta^{34}\text{S}$ ranges from - 6.9 to + 16.0 ‰, with the lightest values from chalcopyrite diseased sphalerite. The white stage is interpreted to have sourced sulphur by remobilisation of grey stage heavy sulphur and from an introduced light sulphur source which accompanied chalcopyrite formation. This light sulphur source has $\delta^{34}\text{S}$ values similar to the light sulphur signatures of the Throssell Group copper deposits.

Lead isotope ratios of galena from Warrabarty and the three Throssell Group copper deposits define a linear trend on Pb-Pb plots, which implies that all deposits formed at approximately the same time. Modelled compositions of possible source rocks indicates that lead was derived from leaching of Throssell Group sedimentary rocks in the vicinity of the deposits. The lead isotope compositions imply an age of approximately 840 Ma, consistent with a syn diagenetic timing for mineralisation at Warrabarty and the copper deposits.

Thermodynamic considerations indicate that the Warrabarty grey stage fluid was capable of transporting reduced sulphur together with metals and that sphalerite precipitation was caused by increasing pH, resulting from dolomite dissolution. The Zn grade of any particular sample is controlled by the coupled dolomite dissolution-sphalerite precipitation reaction. The increase in temperature that occurred from sphalerite deposition to dolomite deposition may have resulted in relatively short-lived sphalerite deposition, thereby contributing to the overall low grade of the deposit. Consideration of Cu and Au solubility data indicates that the Throssell Group white stage fluids were capable of carrying ore forming quantities of Cu and Au; therefore future exploration in the district should consider Cu-Au targets. The Warrabarty grey stage mineralisation shares many features with MVT and Irish-type Zn-Pb deposits, although it cannot be easily classified into either group.

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